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Design and Fabrication of Road Maintenance Machine

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Abstract - *Potholes are one of the most visible and annoying forms of distress associated with bituminous pavement deterioration from the point of view of a road user. Potholes have always been a problem for highway maintenance agencies because their repair is costly and time-consuming. The objective of this newly designed machine is to have an economical and user friendly system for repair of potholes on Indian roads. Many a times, potholes are repaired by non-scientific antiquated techniques and nonstandard materials. It is often seen on roads that potholes are filled in haste by debris/soil, which is usually washed away with the first rain. It leads to a pavement that cannot be repaired and can be made functional only by reconstruction. Therefore, scientific approach involving utilization of standard materials and techniques is essential for long lasting repairs of potholes and patches. Keeping this in mind, our project group has proposed a technological demonstration of a machine to repair the potholes on damaged roads. It is much cheaper than rebuilding the roads again.*

Key Words: **Bituminous Pavement, Deterioration, Potholes, Machine, Roads, Repair**

1.INTRODUCTION

One of the most notable aspects of the development of human civilizations involve the advent of roadways. Roadways have allowed civilizations to exchange goods and services and have provided civilizations with the necessary mobility required for survival. The problem of maintenance of these roadways has persisted to this date and as time has progressed this problem has only become more complex and significant. Development of potholes on Indian roads and streets is a very common phenomenon. India has the second largest road network in the world spanning about 4.69 million km comprising different categories of roads. Only half of the total road network is paved and of the paved roads 90% of them are bituminous pavements. Pavement design is the process of developing the most economical combination of pavement layers to suit the soil foundation and the cumulative traffic to be carried during the design life. The study analyzes pothole problem on the roads of kerala and its causes for assessing the riding quality. In the present work various problematic areas are taken into account to assess the causes of pothole formation and adopt the long-lasting solution to tackle the problem to prevent the deterioration of road surfaces.

Figure -1.1: Pothole in roads

1.1 Pothole Formation

A pothole is a type of failure in an asphalt pavement, caused by the presence of water in the underlying soil structure and the presence of traffic passing over the affected area. The main factors to be considered in the pavement design are: traffic, climate road geometry, position, soil and drainage. Highway pavement is deteriorating fast due to lack of timely maintenance Thus, timely maintenance of the highway pavement is essential. Road maintenance is one of the important components of the entire road system. Right maintenance treatment is to be given to the right place at the right time. Every year millions of rupees are spent by the highway agencies in extensive pothole patch repairs. Because of adverse media coverage these agencies do the repairs of main streets in urban areas and main highways in rural areas after the monsoon season is over. Lanes in towns and cities and some secondary roads in rural areas actually remain neglected for years

1.2 Objectives

Objective of this project is to have an economical and easy system for repair of potholes.We know that a lot of machines available for repair the pothole . The current method for repair the pothole is a labour intensive process and require more time, cost etc. Even repair few or small pothole we need heavier machines using these heavy machines won't be economical so the authorities usually avoid the formation of potholes. Because of that the pothole spreads and become bigger to make worse condition on road.

The repair pothole is being done because of the following reasons:-

i) Preserving a road in good condition
ii) Maintenance of rural road network.
iii) To reduce cost of pothole repair.
iv) To produce environment friendly mixes.
v) To develop labor friendly method.
vi) Sustainable patch pothole repairs.

1.3 Need of Project

The decision to patch potholes is influenced by many factors:

- Reduce the transportation time
- Minimize the traffic jam caused by the bad road condition
- To improve efficiency of vehicles
- Provide better comfort journey
- To reduce the accidents caused by the bad road conditions

2. LIERATURE REVIEW

[1] According to Shahin (1994) , adds that potholes are small usually less than 3ft in diameter bowl-shaped depression in the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. Their growth is accelerated by free moisture collection inside the hole. Potholes are produced when traffic abrades small pieces of the pavement surface. Potholes are most often structurally related distresses and should not be confused with ravelling weathering. When high-severity alligator cracking creates holes, they should be identified as potholes, not as weathering. Cracking is the prerequisite for a pothole to form. After the cracks are formed in the pavement, expansion of the cracks leads to pothole formation.

[2] Wilson T.P. and A.R. Romine (1993), published a paper "Materials and Procedures for Repair of Potholes in Asphalt Pavements" , which recommend high-pressure air blasting, used to remove any dust, debris, and loosened concrete fragments from potholes. Debris must be blown out and away from the pothole so that wind or passing traffic cannot carry it back into the pothole.

[3] In 2018, ShaochengJi et al , found out the relationship between diameter and depth of potholes D = Nh + M, where h and D are, respectively, the depth and mean diameter of pothole, M is a critical size of the initial concavities (seminal potholes) that subsequently underwent growth, and N is the ratio of diameter expanding speed to deepening (floor abrasion) speed. N is generally greater than 1 with an average value of 1.5 M varies from 5.3 cm to 40.5 cm with an average of 20 cm, and N decreases gently with increasing M. Volume of pothole is given by empirical relation V=22.512H.

[4] "How a Tack Coat Improves Your Paving," , in the May issue of Pavement Maintenance & Reconstruction, Proper tack coat application begins with the asphalt distributor used to deliver the tack coat material to the existing pavement surface. The tack coat material in the distributor tank must be kept at the proper temperature to assure that the material can be sprayed uniformly onto the existing pavement surface. When an asphalt emulsion is used, it should normally be applied at a temperature between 49°C and 71°F. It is very important to have the tack coat material at the proper application temperature in order to obtain a uniform distribution on the existing pavement surface. For a clean, tight surface the residual amount of tack coat required will generally be of 0.14 litres per square meter.

[5] N.F. Ghaly, et al, in his publication, "Tack coats for asphalt paving", defines tack coat as an application of bituminous material to an existing relatively non absorptive surface to provide a thorough bond between old and new surfacing Normally, hot bituminous binders, cutback bitumen's (bitumen–solvent base) and/or bitumen emulsions (bitumen–water base) are used as tack coat materials. Tack coats are sprayed in a thin film on the existing layer surface before the construction of the next pavement layer. After the tack coat wets the surface of the old pavement and fills the tiny pores, it solidifies and develops what is called interlocking. This interlocking is strongly affected by the liquid's viscosity at installation. Low viscosity tack coat can penetrate and follow the surface irregularities better than the high viscosity tack coat and, hence results in a better interlocking.

[6] IRC:82-1982 "Maintenance of Bituminous Surfacing of Highways", deals with routine maintenance of flexible pavements including repair of potholes.
According to Bureau of Indian Standards, IS 3066 the difference in the temperature of aggregate and bitumen shall not exceed 150 C. In order to ensure uniform quality of mix the plan shall be calibrated from time to time. The breakdown rolling shall be done with an 8 to 10 tonnes dead weight or vibratory steel wheel roller. The Natural Resources Research Institute, University of Minnesota Duluth, MN has recently completed a report regarding the use of taconite-based materials in pothole repair. The study examined repair using Rapid Patch, a material developed by NRRI. Tanks for storage of bitumen shall be equipped for heating the material, under effective and positive control at all times, to the temperature requirements set forth in the specifications for the paving mixture. Heating shall be low flame temperature oil burners. If oil burners are used, fire brick, cast iron or other suitable liners shall be provided so that the flame cannot impinge directly on the tank plates. Gearing shall be designed to have ample strength and to adequately withstand wear and temperature rise. They shall, as far as

possible, conform to the requirements of I S: 25351963. Molded teeth may be used for pitch line speeds not exceeding 30 m/min

3. COMPONENTS AND DESCRIPTION

The major components used in the Road Maintenance Machine are;

3.1 Frame

The components of machine called compressor, tack coat storage tank, mixer, pump etc, are fixed on a rigid frame. For making the frame, a MS angle of dimension 20*20*3 mm is used and this welded together so as to form a rectangular frame of 92cm*48cm. In order to support the components cross beams are made and is welded onto the frame. MS Angles are L-shaped structural steel represented by dimension of sides & thickness. MS Angles are used in various construction , engineering and fabrication activities, Mild Steel Angles are most commonly used steel structural item. Frame was the created by the process cutting, bending, and assembling processes. Mild steel is a type of carbon steel with a low amount of carbon. Although ranges vary depending on the source, the amount of carbon typically found in mild steel is 0.05% to 0.25% by weight, whereas higher carbon steels are typically described as having a carbon content from 0.30% to 2.0%.

Fig-3.1: Frame

3.2 Compressor

A compressor is a mechanical device that increases the pressure of a gas by reducing its volume. An air compressor is a specific type of gas compressor. An air compressor is a device that converts power into potential energy stored in pressurized air (i.e., compressed air). By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure. When the tank's pressure reaches its engineered upper limit, the air compressor shuts off. The compressed air, then, is held in the tank until called into use. The energy contained in the compressed air can be used for a variety of applications, utilizing the kinetic energy of the air as it is released and the tank depressurizes. When tank pressure reaches its lower limit, the air compressor turns on again and re-pressurizes the tank. In our machine air compressor which delivers 35 bar pressure is bolted onto the cross beam, similarly air storage tank is made using GI pipe of 9cm diameter, whose ends are welded with steel plate. Copper tube of 4mm diameter is used as carrying medium of compressed air from compressor to air storage tank and from air storage tank to the delivery. A ball valve is used to control the flow of air from the nozzle. The cu tube of diameter 3 mm which supplies compressed air at high velocities.

Fig-3.2: Compressor

Specifications;
Type-Reciprocating

Volt - 220v Ac	Watts - 110	Piston Diameter - 20mm
Amps - 500MA	RPM - 2880	Stroke length - 20mm

3.3 D.C Motor

DC motors were the first form of motor widely used, as they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field winding's. Small DC motors are used in tools, toys, and appliances. The universal motor can operate on direct current but is a lightweight brushed motor used for portable power tools and appliances. Larger DC motors are currently used in propulsion of electric vehicles, elevator and hoists, and in drives for steel rolling mills. The advent of power electronics has made replacement of DC motors with AC motors possible in many applications.

Fig-3.3: motors

Specifications;

Volt - 12v	RPM - 3000
Amps - 50	Watts - 600

3.4 Water Pump and Tank

The water pump and tank is used to spray water to the roller unit for avoid the sticking of tar in to the roller unit. The tank is a simply water storage unit into that a pump is attached. The pump sprays the water in to the roller unit when the vibrator in the roller works. The pump works at 9v Dc supply and having power of .1HP. Tip of the nozzle is connected to the tube which will carries the water to the roller unit.


Fig-3.4: Pump and tank

3.5 Ball Bearing

A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races. The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. It achieves this by using at least two races to contain the balls and transmit the loads through the balls. In most applications, one race is stationary and the other is attached to the rotating assembly (e.g., a hub or shaft). As one of the bearing races rotates it causes the balls to rotate as well. Because the balls are rolling they have a much lower coefficient of friction than if two flat surfaces were sliding against each other

Fig-3.5: Ball bearing

Ball bearings tend to have lower load capacity for their size than other kinds of rolling-element bearings due to the smaller contact area between the balls and races. However, they can tolerate some misalignment of the inner and outer races
Selection of Bearing = SKF 6202
Material = Steel
Thickness of Bearing (B) = 12 mm
Maximum Speed = 15,000 rpm

3.6 Gear Wheel

A gear or cogwheel is a rotating machine part having cut teeth or, in the case of a cogwheel, inserted teeth (called cogs), which mesh with another toothed part to transmit torque. Geared devices can change the speed, torque, and direction of a power source. Gears almost always produce a change in torque, creating a mechanical advantage, through their gear ratio, and thus may be considered a simple machine. The teeth on the two meshing gears all have the same shape. Two or more meshing gears, working in a sequence, are called a gear train or a transmission. A gear can mesh with a linear toothed part, called a rack, producing translation instead of rotation. The gears in a transmission are analogous to the wheels in a crossed, belt pulley system. An advantage of gears is that the teeth of a gear prevent slippage. When two gears mesh, if one gear is bigger than the other, a mechanical advantage is produced, with the rotational speeds, and the torques, of the two gears differing in proportion to their diameters.

Figure3.6: Gearwheel

In transmissions with multiple gear ratios such as bicycles, motorcycles, and cars—the term "gear" as in "first gear" refers to a gear ratio rather than an actual physical gear. The term describes similar devices, even when the gear ratio is continuous rather than discrete, or when the device does not actually contain gears, as in a continuously variable transmission.
Type = Spur gear No. of teeth on driving gear = 96
Material = Mildsteel No. of teeth on driven gear = 8

3.7 Air Storage Tank

Air receiver tanks are essential to compressed air systems, as they allow the system to perform efficiently. They also serve as temporary storage. The tanks enable you to use air when the compressor is not running. Apart from this, they also supply additional air to the system during periods of high usage. An air receiver is a type of pressure vessel; it holds compressed air under pressure for future use. The tanks come in a range of sizes and in both vertical and horizontal configurations. Storage tank is made using MS pipe of 9cm diameter. A copper tube is used for carrying compressed air from the compressor and delivers it in to the valve

Tack Coat Storage Tank

Tack coat is a special bitumen emulsion. based on high quality bitumen and fillers. It is a thixotropic, cold applied high build bitumen based coating. The dry film of tarcoat provides a watertight barrier, which is highly resistant to chlorides and sulphates/present in the soil. Tack coat is ideal for the various process due to its ease of application. Tack coat is more viscous fluid and it cannot be freely sprayed through a nozzle. So a part of compressed air is fed into the tack coat storage tank from the air storing tank using t-joint. This will increase the pressure inside the tack coat tank and the compressed air easily pushes the high viscous tack coat across the nozzle resulting in smooth spraying of tack coat over the pothole. The flow is manually controlled by an ordinary boll valve. The tank is made from MS pipe. It consists of 9cm diameter and 35cm length. And there are three holes made in the tank for pouring of tack coat into tank, tack coat flow from the tank and compressed air flow into the tank.

Fig-3.7: Air and tack coat storage tanks

3.8 Roller

Rollers use the weight of the vehicle to compress the surface being rolled (static) or use mechanical advantage (vibrating). Initial compaction of the substrate on a road project is done using a padfoot drum roller, which achieves higher compaction density due to the pads having less surface area. The roller is made up of 14cm diameter MS pipe and 28cm length which weights 20kg. To increase the weight of the roller we add a provision for putting more weight

Fig-3.8: Roller

3.9 MIXER UNIT

The mixer drum dimension is 30 cm diameter and 30 cm length. Firstly, the frame for mixer drum was made by using MS flat of 25mm width and 3mm thickness. A 30 cm MS sheet is also made across the frame supporting the frame. After the frame is made, the frame is covered with thin metal sheet and is welded. The provision for entrance and exit of mix was made on the sheet before welding it completely on the frame. Then a gear of 24 mm diameter and 96 teeth is welded onto the mixer shaft. Two bearings SKF 6202 is used to carry the load of shaft to the frame. Later the gear is mated with a smaller gear or pinion of a geared motor of 60 W power which rotates at 30 rpm. A can butane is used, in order to heat the mix

Fig-3.9: Mixer unit

3.10 Butane Cylinder

Butane is an organic compound with the formula C4H10 that is an alkane with four carbon atoms. Butane is a gas at room temperature and atmospheric pressure. Butanes are highly flammable, colorless, easily liquefied gases that quickly vaporize at room temperature.Normal butane can be used for gasoline blending, as a fuel gas, fragrance extraction solvent, either alone or in a mixture with propane, and as a feedstock for the manufacture of ethylene and butadiene, a key ingredient of synthetic rubber. We use butane burner for melting of the tar

Fig-3.10: Butane cylinder

4. WORKING

The road maintenance machine works on DC supply except the AC compressor. The power source of the machine is 12v DC battery. The machine consists of a compressor that compressor that compress the atmospheric air and stores into air storage tank through a cu tube. Some amount of air taken by the tar coat storage tank used to maintain the pressure of tar coat. The compressed air is released with ball valve then the dust and the debris in the pothole will be removed. After that the pressurized tar coat released into the pothole from storage tank with help of ball valve.

The mixer unit rotates in its axis with the help of motors. Place the tar and tar coat into the rotating mixer unit. There is a burner is attached near to the mixer unit it will

melts the tar. The rotation of mixer unit makes appropriate mixing of tar and tar coat. Then apply the mixer into pothole. The fixing of pothole done by roller and vibrating unit. Vibrator unit consists of a motor that producing vibration and it controlled by a switch. when the vibrator works the pump attached into the water storage tank pumps water into the roller to avoid the sticking of the tar in to the roller

5. DESIGN

The Road maintenance machine consist of five units, namely the pothole cleaning unit, tack coat spraying unit, tar and gravel mixing unit, water spraying unit and the roller and vibrator unit. This section shows the design of the elements present in the machine. Fabrication of all elements in the machine were done on the basis of design as shown below. All the units like compressor, tack coat storage tank, mixer etc. is fixed on a rigid frame. For making the frame, a hollow steel pipe is used and is welded together so as to form a rectangular frame. In order to support the components cross beams are made and is welded onto the frame. The first consideration in the design of the prototype was the determination of its size. Several factors influenced this decision. The Road maintenance machine must be robust to be able to operate satisfactorily in field tests. It must be able to carry significant loads (filler material). It should also be large enough to house a power unit to be used for control. Keeping these factors in mind, it was decided to use MS angle as the building frame for the machine. The Road maintenance machine is built upon the base frame of an MS angle pieces joined by welding. The frame is 62-cm long, 48-cm wide, with a maximum height of 48-cm. It is capable of supporting a weight of approximately 100 kg. On this frame other machine components are fixed using nuts and bolts and welding process.

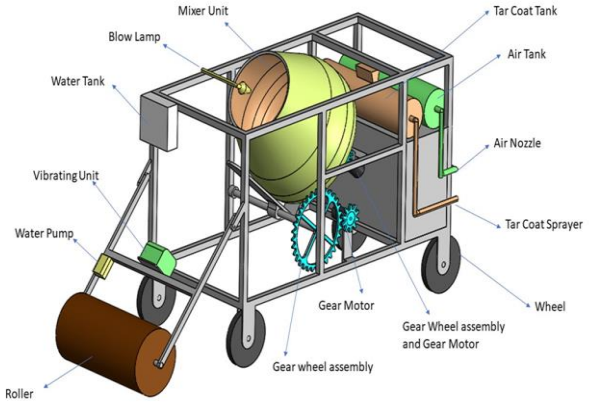

Fig-6.1: Design of road maintenance machine

6. CALCULATION

6.1 Tack Coat Spraying Unit

A horizontal cylindrical tank is used to store tack coat. The tank is mainly loaded with internal pressure, being the sum of hydrostatic pressure and uniform pressure caused by the vapour of contained medium Total internal pressure:

$P=Ph+P0$

$Ph=\gamma a\ (1-\cos\theta)$

Where,

Ph - internal hydrostatic pressure,

Po -internal uniform pressure caused by the vapour of the liquid,

γ - specific weight of the tack coat

a- radius of cylindrical shell.

θ - Circumferential angular coordinate

Specific gravity of tack coat is known as 1.01.

Hence the density of tack coat = 1.01 1000 =1010 kg/$m3$.

Specific weight of the tack coat, γ =1010 9.81= 9908.1 N/$m3$.

Radius of cylinder tank used, a= 4.5cm.

For θ = 3.14 / 2,

Ph=γ a

=9908.1 .09= 891.73 N/ $m2$

Which is very small compared to the allowable pressure withstanding capacity of tank.

Capacity of the tank is

Where,

σ σ-relative length of the cylindrical tank.

V=3.14*4.5*4.5*4.5*4.2=1.2Litres

Then volume of tack coat inside tank = 1.2 litres.

6.2 Design of Air Storage Tank Based on Strength

Compressor compresses the air at a maximum pressure of 35 bar. The air storage tank used is a cylinder, of 9 cm internal diameter with 2mm thickness and of length 25cm. Material used for air storage tank is MS pipe. According to Lames equation for pressure vessel thickness,

Ultimate tensile strength of Mild steel =400MPa

F.O.S= 2.5

Lames equation for pressure vessel thickness,

$$t = \frac{D}{2}\left(\sqrt{\frac{\sigma_t + p_i}{\sigma_t - p_i}} - 1\right)$$

Where,

t -Thickness of the cylinder =2mm.

d -Diameter of the cylinder= 9cm.

$$\sigma_t = S_{UT}/FOS$$

SuT=ultimate tensile strength=400MPA
FOS- factor of safety = 2.5

Then we get,

$$2 = \frac{90}{2}\left(\sqrt{\frac{400/_{2.5}+p_i}{400/_{2.5}-p_i}} - 1\right)$$

We get value of Pi as 5.28MPA. Our required internal pressure is 35bar which is 3.5 MPa.Since the pressure which can be withstand by the cylinder tank is more than the compressed air pressure, the air storing cylinder is safe in terms of strength. Hence the design of air storing tank is completed.

7. FABRICATION PROCESS

- Cuts the MS angle into 12 pieces as in the dimension 90*47*47 and by welding made a rectangular frame using this Ms angle pieces.
- Using 9cm diameter MS Pipe Air and takcoat storage tanks are made. Also the Roller is made from the MS Pipe of 14cm diameter.
- Their is CU tube is connected to the storage tanks for carrying compressed air from the compressor.
- The mixer unit is made by rolling the MS Plate at a diameter of 30cm. It connected by welding and the bottom surface of mixer unit covered by a 30cm diameter piece of MS flat.
- Their is a gearwheel is attached to the backside of the mixer unit and it engages with a motor consists of a pinion gear situated in the frame
- Then mixer unit is connected with the bearing bed by welding and then bearing bed is coupled to the frame, SKF 6202 bearing is used here
- The air and takcoat storage tanks are fixed on the frame with the clamaps.
- Then roller is connected to bearingbed and it attached to the frame by welding
- Above the roller a vibrator motor is attached for smooth fixing of tar and a water pump attached to the frame
- After assembling of parts electrical circuit works are done
- After that electrical connection to vibrator, pump, compressor and Motor are provided by switching relay, power supply taken from a battery.
- At last the product road maintenance machine is fabricated and ready for the testing.

Fig-7.1: Proposed machine

8. EXPECTED RESULT

The accompanying operational necessities are viewed as significant for fixing of pothole using the machine. One individual is expected to operate the machine and put the mix into pothole from the mixer drum and compact the mix in pothole using the roller vibrator. Machine can be operated by DC power supply at the site. Precaution must be taken during operation of the machine. The operator should wear hats, vests and boots. Operator must be cautious and should look after for the vehicles moving through road. The operation of machine should not create any traffic troubles to vehicles moving through the road. Training is required for controlling the switch panel and visual observations of pothole.

9. CONCLUSIONS

The project described in this report dealt with the design and fabrication of road pothole repairing machine by incorporating all the conventional method techniques to repair pothole onto a single machine unit. The machine was fabricated successfully as per the design considerations and is mounted on four-wheel support. All the units and parts accompanied in the machine perform the related task without any kind of malfunctioning. The machine is easy to carry, compact, and even unskilled individual can operate it The machine was tested for a number of times and it's found that each time there occurs a problem and had to correct it on the later trials. The final trial after correcting all the mistakes from the previous trials, observed to patch pothole efficiently, in less than 15 minutes. The pothole has been sealed successfully, but still lack in perfection due to inexperience of operator regarding road tarring and also due to low compaction force associated with roller.

10. ADVANTAGES

1. Fast patching- the average pothole can be patched in just 15 minutes.
2. All the functions can be controlled with simple switches.
3. Repairs utility cuts and long cracks in one continuous operation.

4. It would carry out long lasting repairs to potholes. Clear visibility to the operator.
5. Easy to carry so could be taken to any remote place too.
6. Unskilled labour could easily operate the machine.
7. Urgent patches could be made which is usually considered to be impractical in the past. Immediate patching allows less alteration to the traffic condition

11. RECOMMENDATIONS

The current work is just a technical demonstration showing assemblage of different units associated with road maintenance into a single machine and using that machine to seal a single pothole of at most 30cm at a time. The real machine on the other hand, should be of bigger size which can carry more mix and can seal more than one pothole at a time. Mixer was made manually for this machine by sheet metal operations. In real practice for an original machine, this should be done using CNC machine so as to get perfect shape and that too without any margin of error. It is found that the roller in the fabricated machine lacks perfect compaction force required to compact the pothole. As the machine is a miniature model, it is difficult to assemble heavy compact roller onto this model. Actual machine which has much bigger size, would have assembled with large and heavy roller so as to get good compaction force sufficiently enough to seal the pothole

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